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APPLICATION OF PROCESS MONITORING TO VERIFY FACILITY DESIGN*

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ABSTRACT

Process monitoring has been proposed as a safeguards measure to ensure that a facility is operating as designed, or as a surveillance measure to ensure that material is not removed from the facility in an undeclared manner. In a process-monitoring system, the facility operator monitors process operations such as tank levels, densities, and temperatures; process flows; and physical parameters such as valve positions to ensure that the operations performed are both desired and required. At many facilities (for example, Idaho), the process-monitoring system is also an important safety feature to prevent criticality.

Verifying facility design is necessary for application of safeguards in a reprocessing plant. Verifying all pipes and valves through comparison of blueprints with the as-built facility is an almost impossible task with the International Atomic Energy Agency's limited inspection resources. We propose applying process monitoring for international safeguards facility design verification. By carefully selecting process-operating variables, it may be possible to verify that plant flows are as described and that key measurement points are not bypassed.

I. INTRODUCTION

Design information verification is a required element for international safeguards as practiced under INFCIRC-153[1] for signatories to the Non Proliferation Treaty (NPT). Paragraph 43, which specifies the design information to be made available, includes

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(a) facility identification;

(b) facility description, including location and flow of nuclear material;

(c) description of the features of the facility relating to material accountancy, containment, and surveillance; and

(d) description of the existing and proposed procedures at the facility for nuclear material accountancy and control, with special reference to material balance areas (MBAs) established by the operator, measurements of flow, and procedures for physical inventory taking.

Proposed procedures for design verification of large reprocessing plants[2] include, among other things, a review of the following information:

- the chemical process flow sheet, giving flow rates, acidity, density, uranium and plutonium concentrations and β,γ activities at plutonium measuring points (no other data that are likely to show the process chemistry "know-how" are required);

- a Process and Instrumentation Diagram (PID) (from the standard PID, which is a basic design document, only the sections concerning dissolution, feed clarification, input tank, all tanks in the plutonium lines, plutonium output tank, and plutonium product storage tank are required);

- a description of such parts of the process control system that are necessary for understanding the entire measuring process from measurement points to data acquisition and processing features; and

- a data acquisition and processing system.

Some suggested verification activities during functional testing of the plant include

- examination and checks required for installed safeguards relevant components [dissolver(s), feed clarification devices, plutonium evaporator], concerning input and output piping connections, and

- identification and checks of input accountability, plutonium product, and all other tanks in the plutonium process line, including input and output piping connections and "all other details." It is suggested that the Agency team observe the entire sequence of mechanical and hydraulic tests and evaluate these tests jointly with the operator.

Some of the verification activities suggested during cold commissioning include

- follow up and check the procedures and results of calibration and sampling of the input and output tanks and all tanks where plutonium is to be measured (confirm that the operator has established well-defined, written procedures for tank calibration and sampling and maintains a continuously updated copy);

- follow up and check the procedures and results for testing and calibrating the measurement instruments, the transfer systems (including dilution and "dead volumes" involved), and the auxiliary services provided for every tank;

- follow up and check the sampling procedures and the calibration of measuring and monitoring instruments foreseen for each key measurement point (KMP);

- follow up and check the sample transfer equipment and procedures for the laboratories;

- verify the calibration of nondestructive assay instruments to Agency standard; and

- verify the proper location, installation, and calibration of surveillance equipment and systems, and check the false-alarm rate.

Also, the inspector should experimentally test and validate process models used to assess the quantity of nuclear material present in process equipment at predetermined process conditions.

Although this represents only a partial list of suggested inspector verification activities, it is apparent that design verification is a formidable task and will require a team of knowledgeable engineers to do the job effectively and efficiently.

Most reprocessing plants in operation or under construction will have some form of process monitoring to aid the operator in reading and assessing process status for safety and process control purposes. We propose that some aspects of the process monitoring system can be used for facility design verification.

II. DEFINITION AND FUNCTION OF A PROCESS MONITORING SYSTEM

Process monitoring is incorporated or is being considered for most reprocessing facilities to ensure efficient and safe plant operation.[3-5] One definition of process monitoring is "...the broad use of process data to make judgments about the location and movement of nuclear material in the facility."[6] Basic considerations that would be incorporated in a process monitoring system could include

- acquisition of data from sensors installed in a process environment that indicates directly or indirectly conditions of process materials and equipment,

- operations on that process data with analysis systems to generate appropriate parametric tests, and

- provision of response criteria that are consistent with stated functional objectives.

Process sensors may include tank levels, densities, and temperatures; valve positions; and material transfer rates (for example, flow meters). Data collection may be essentially continuous; for example, systems studied at Barnwell[7] and Oak Ridge[4] collect data every four minutes. Therefore, a computer system is required for data collection and evaluation.

Although process monitoring systems have been designed primarily to determine the movement and location of nuclear material and/or solution for process control and criticality safety, their use has been promoted for nuclear safeguards, both domestic and international.[3-7]

There are major differences between objectives and the use of information for domestic and international safeguards. In using process monitoring for domestic safeguards, both the work at Idaho National Engineering Laboratory (INEL)[5] and the study sponsored by the Nuclear Regulatory Commission[7] rely on process monitoring to determine that unrecorded transfers have not taken place within the process. This information is used to draw conclusions that materials reside in declared locations. However, in international safeguards the inspector verifies operator-declared transfers into and out of the MBA, and the location and quantity of material within the MBA. The latter is performed through verification measurement of the material in order to draw a conclusion of material unaccounted for (MUF) and the limit of error of MUF (LEMUF) as required by INFCIRC-153. Thus, even though the inspector has access to process monitoring information within the process, it is not clear how he could use it to draw quantitative conclusions.

III. ELEMENTS OF A PROCESS MONITORING SYSTEM

Following is a brief review describing the elements and functional capabilities of two process monitoring systems proposed for safeguards use.

A. INEL

The process monitoring system at the INEL high-enriched uranium fuel reprocessing facility has evolved over several years.[5] The system scans approximately 1500 variables from 125 process vessels once per minute. The process comprises the head-end dissolution, a TBP extraction cycle, two hexone extractions, and a denitration step. Interprocess accountability points are the first cycle, between the first cycle and intercycle storage, between intercycle storage and the second and third cycle, and between second and third cycle and the denitration operation. All accountability is by difference. All transfers are performed on a volume balance; concentration measurements are not included in the database. For safeguards purposes, the monitoring criteria are to detect transfers across sub-MBA boundaries and to assure integrity of accountability measurements.

B. The Oak Ridge National Laboratory System

The Integrated Equipment Test (IET) facility at Oak Ridge was designed as a reprocessing plant equipment development facility. It includes feed preparation, solvent extraction, and product concentration equipment. A computerized process control and data acquisition system is interfaced to all process control instruments and control equipment. Data are collected every four minutes. Typical process control measurements include density, level, and temperature of tanks; flow rates; and some concentration using in-line spectrophotometry. A series of analysis routines was developed to analyze the process monitoring data for various applications, including identification of anomalous data (for example, plugged dip tubes). As examples, mass flow of heavy metal through the solvent extraction system can be monitored using the feed tank drop-out rate, flow meter measurement, and in-line photometry for concentration measurement. Volume transfers between tanks are balanced and checked for consistency and identification of possible volume losses.

IV. APPLICATION OF PROCESS MONITORING TO DESIGN VERIFICATION

Process monitoring has been proposed as a safeguards measure for reprocessing plants, both for domestic and international purposes.[3-6] The International Atomic Energy Agency (IAEA) studied possible applications for international safeguards and identified three major problems:[5]

- The inspector requires access to extensive process information, much of which may be considered proprietary or sensitive by the operator.

- The problem of false alarms and their resolution has not been addressed, and it may be difficult to unambiguously interpret data.

- The IAEA requires that safeguards data can be independently verified or authenticated. It is not clear that this can be adequately addressed in a complex process monitoring system.

Thus, in an operating reprocessing plant, it is questionable whether process monitoring will be an acceptable international safeguards tool.

Use of process monitoring for design verification does not require the same types of information as are required for safeguards. For example, verification of transfers between tanks or through the solvent extraction system can be accomplished on a volume transfer basis; concentration should not be required. As noted in Sec. I, major inspector design verification activities address assurance that KMPs are not bypassed; that the measurement system (including samplers) functions as declared; and that tank volumes, transfers, and process models used to assess the quantity of nuclear material in process equipment (contactors, evaporators) is as declared.

Following are process monitoring functions that could be used for design verification.

A. Verification That KMPs Are Not Bypassed

The major process KMPs are the input and output accountability tanks. Process monitoring during cold testing could verify that transfer from the dissolver reaches the input accountability tank, and that transfers from the input accountability tank are transferred only to the process feed tank.

Similarly, the flow paths through the product accountability tank can be verified. For example, the Oak Ridge process monitoring system can detect undeclared transfers to the process, addition of samples after sampling and measurement, and undeclared additions during accountability transfer (Ref. 6, p. 20).

B. Verification of Tank Volume and Transfers Between Tanks

This type of activity is an integral part of both Idaho and Oak Ridge process monitoring systems.

C. Verification of Nuclear Material in Process Equipment (Contactors, Evaporators)

The verification of volume and solution weight balance through the solvent extraction process is a design feature of the Oak Ridge process monitoring system. In fact, the use of this routine was suggested by Ehinger as a demonstration of process monitoring for design verification (Ref. 6, p. 51).

V. FUTURE WORK

Application of process monitoring to verification of facility design must be approached on a facility-specific basis. The approach should include

- process design evaluation,
- process operating features,
- process monitoring features, and
- diversion possibilities.

One should consider what proprietary information may be required. It appears intuitively that this would be minimal because during the design verification period the process need not be operated using design-basis flow-sheet data.

It was noted in Sec. IV that false alarms and their resolutions are a problem in applying process monitoring for safeguards during operation. False alarms should not be as significant a problem for design verification, but the question of anomalous data and resolution of these anomalies needs to be addressed.

The authentication of the process monitoring system has not been addressed in this paper. It is clear that the inspector, in applying process monitoring to design verification, must be assured that the signals he is using are as declared. In some cases, use of redundant process monitoring data may minimize this concern.

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